

RADAR INSPECTION OF CONCRETE, BRICK AND MASONRY STRUCTURES

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INTRODUCTION

Seismic radar was introduced as a geophysical tool for mineral exploration in the 1970's. Since then, there have been several attempts to use the technique to assess civil engineering structures. For example: Bridge decks and masonry tunnels [1, 2], concrete [3], bridge decks overlaid with asphalt [4,5], concrete and masonry tunnels [6], detection of voids under jointed concrete paving [7], location of piles under an old concrete floor [8] and the location of leaks in underground pipes [9]. These few references are not intended to be a comprehensive survey, but do indicate the variety of problems for which radar has claimed to be the ideal inspection tool.

In the United Kingdom, radar techniques first established themselves with the investigation and subsequent demolition of a sub-standard block of flats at Ronan Point in 1984. This followed damage from an explosion there in 1968. Other methods can be used to assess concrete quality. Ultrasonic pulse velocity is one but is usually used to give only spot measurements at a number of points. Radar has the potential to survey whole areas at an acceptable speed.

Maintenance of bridges and roads may become closely tied to radar surveys, since bridge cover can be measured accurately and areas of poor compaction or cracking detected. The design life of a road can be reduced by 25% if the design thickness is reduced by only 4% [10].

Despite this potential, the civil engineering industry is slow to adopt radar technology. We believe this is because some claims for the capability of radar have been overstated and the data generated is difficult for the non-specialist to understand. The

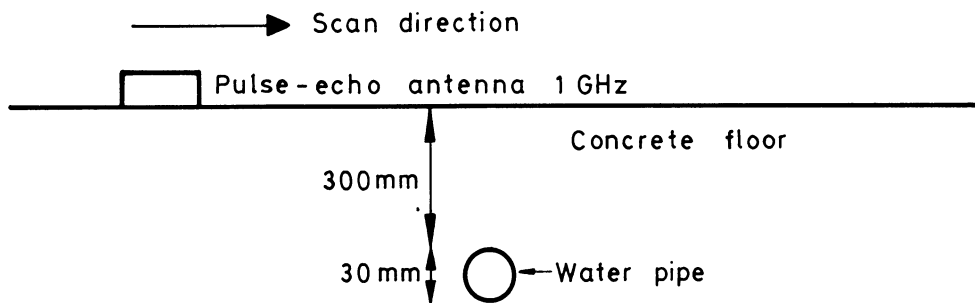


Figure 1. Geometry of a pulse-echo radar scan at 1GHz over a small waterpipe buried in concrete.

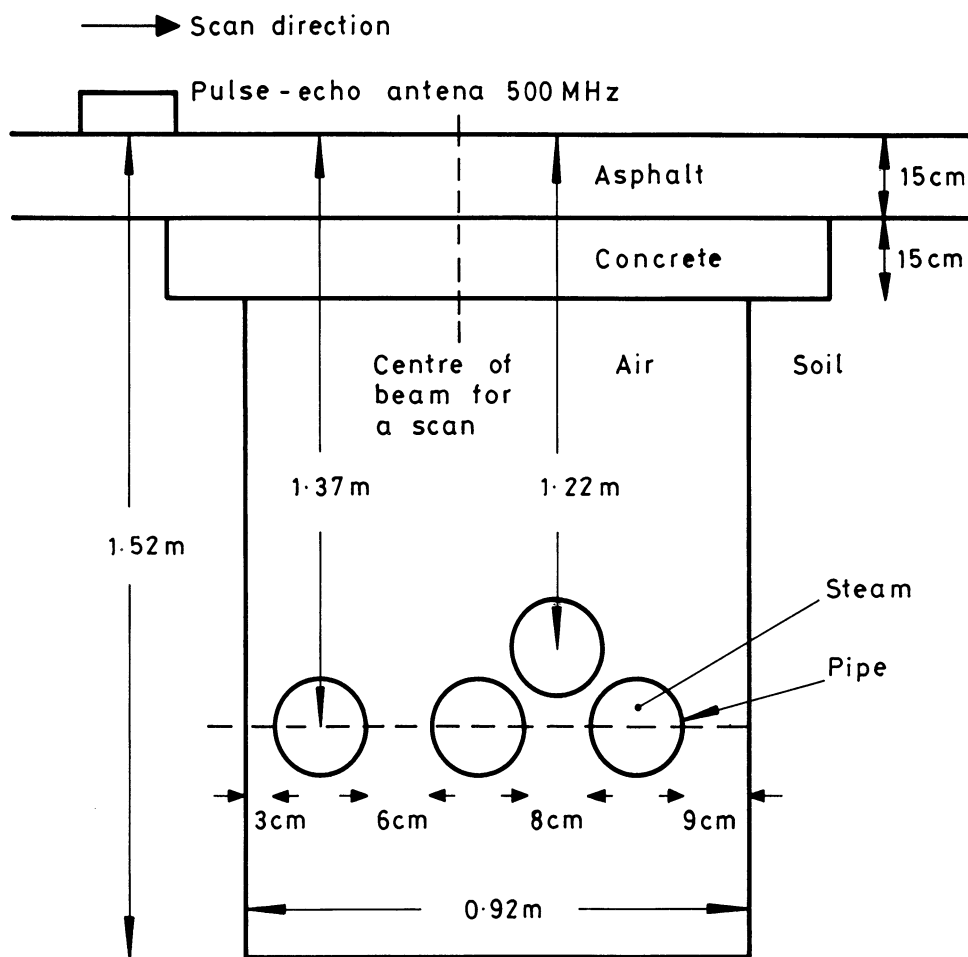


Figure 2. Geometry of a pulse-echo radar scan at 500 MHz over a buried tunnel containing steam pipes at unknown locations. Also shown is the position of the antenna for the A-scan shown in figure 6.

situation seems to be very like that pertaining in ultrasonic inspection of metallic components fifteen years ago. At that time, modelling was first introduced with the result that understanding developed of techniques and their limitations and new, more capable, techniques could be designed efficiently. This is the process we are now applying to radar inspection. The two geometries we have modelled are shown in figures 1 and 2.

MODELLING

Modelling radar scattering relies simply on the boundary conditions at each interface in the material. These are the Frenet equations

$$\hat{n} \times (\underline{E}_i + \underline{E}_r) = \hat{n} \times \underline{E}_t \quad (1)$$

and

$$\hat{n} \times (\underline{H}_i + \underline{H}_r) = \hat{n} \times \underline{H}_t \quad (2)$$

where \hat{n} is the outward pointing surface normal and subscripts i, r and t stand for incident, reflected and transmitted fields, respectively. Within each material i, the complex wave vector is given by

$$\kappa_i^2 = \omega^2 \epsilon_i \mu_i + i \sigma \omega \mu_i \quad (3)$$

where ω is the angular frequency, ϵ the dielectric constant, μ the permeability and σ the conductivity. For a material with many interfaces, as expected in civil engineering structures, a choice needs to be made between treating each interface exactly, but having to perform complicated ray tracing to take account of all multiple reflections, or taking account of the effective propagation, though many interfaces at the expense of oversimplifying the geometrical relationships between interfaces. We choose the latter approach as a viable way of producing useful information on a personal computer in an acceptable time - say under five minutes for a realistic B-scan, such as later examples.

A short pulse, of single cycle sine wave, from a finite length antenna is modelled. The complex reflectivity of the structure along a number of rays passing through it, is calculated at 1024 frequencies for each source position. The complex reflectivity is applied in the frequency domain and the resulting time domain signal recovered by a digital fast fourier transform. McCavitt and Forde [11] used single interface techniques inside a convolution integral to achieve the same effect for masonry arch bridges.

EXPERIMENTS

Commercially available impulse radar equipment was used at 1GHz and 500 MHz to examine the structures shown in figures 1 and 2. Data was collected and signal processing techniques adapted from standard ultrasonic methods were applied to yield the B-scans shown in figures 3 and 4. Output from the models for the two cases is shown in figures 5 and 6.

RESULTS

Figure 1 is for a water pipe approximately 30 mm diameter embedded in a concrete floor at a depth of about 300 mm. The B-scan obtained experimentally at 1 GHz is shown in figure 3 with the associated model results in figure 5.

Figure 2 is for a collection of pipes believed to be in an underground tunnel covered with both concrete and asphalt. Details of the size and layout of the pipes, which run under part of the Harwell site, are not known definitely. The experimental results obtained at 500

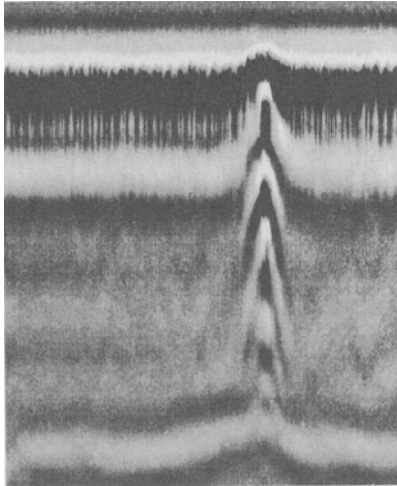


Figure 3. Radar data from a small pipe buried in concrete with a 1 GHz probe. Horizontal and vertical scales are similar to those in figure 5.

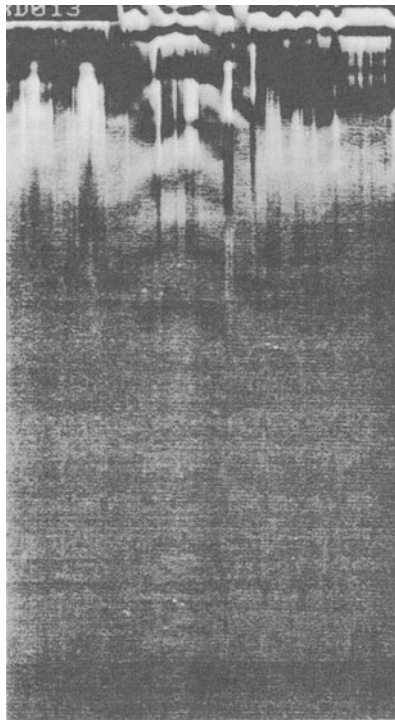


Figure 4. Radar data for pipes in a duct under a roadway with a 500 MHz probe. Horizontal and vertical scales are similar to those in figure 6.

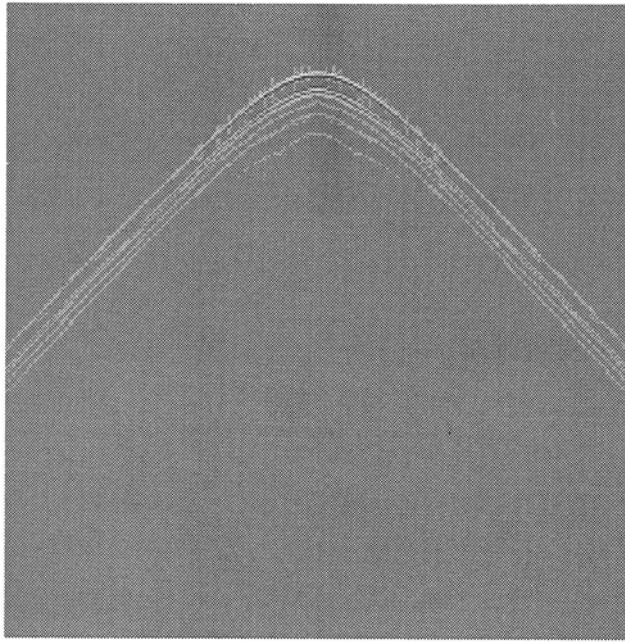


Figure 5. Model predictions for B-scan with 1GHz probe scanning over a small water pipe buried in concrete. The horizontal width of the figure represents 3m with 256 scan positions. The vertical scale represents a time of about 4×10^{-8} seconds.

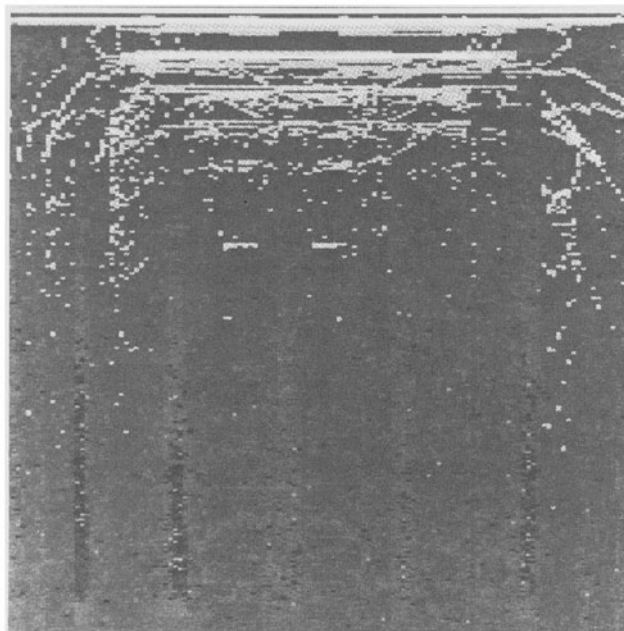


Figure 6. Model B-scan through a section of the buried tunnel containing steam pipes. The vertical scale is amplitude in arbitrary units, the horizontal axis represents a time window of about 10^{-7} seconds.

MHz are shown in figure 4, with an B-scan from the corresponding theoretical predictions in figure 6.

This demonstrates the potential of signal processing techniques applied to radar signals and of the potential for modelling to assist on-site assessment of radar data.

DISCUSSION

Commercial ground probing radar has been used with standard ultrasonic signal processing techniques to yield images which are much clearer than those normally associated with radar surveys.

Progress has been made towards the goal of modelling such B-scan images as an on-site interpretative tool.

ACKNOWLEDGEMENT

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